



TOWN OF BROOKLINE

Department of Public Works
333 Washington Street
Brookline, MA 02445-6863

Bicycle Facility Assessment

Beacon Street Westbound Side

From Marion Street to Washington Street

Brookline's Transportation Division prepared this assessment to determine if bicycle accommodations can be provided on the westbound side of Beacon Street from Marion Street to Washington Street, also known as Corey Hill. **Figure 1** shows the study area. This section of Beacon Street is identified in the Brookline Green Routes Bicycle Network Plan as a particularly dangerous section for cyclists. The Green Routes' plan request the area be comprehensively studied and a safe bicycle improvements plan be developed.

The pavement width of this section of Beacon Street could accommodate a bike lane if one of the two westbound travel lanes on Beacon Street are removed or one lane of parking is removed. Due to the high parking demand and limited supply in this area removing a parking lane is not practical. This assessment will determine if the Beacon Street westbound side can operate with one motor vehicle travel lane removed starting at Short Street and returning to two lanes near Westbourne Terrace while still maintaining reasonable level of service.

The three major intersections in the study area are Beacon Street at Marion Street, Beacon Street at Lancaster Terrace and Beacon Street at Washington Street. These three intersections will be studied in detail to determine the ability of these intersections and the corridor as a whole to function adequately with a motor vehicle travel lane removed.

EXISTING CONDITIONS

Roadways

Beacon Street is classified by Massachusetts Department of Transportation as an Urban Principal Arterial under local (town) Jurisdiction. Beacon Street crosses the most densely populated part of Brookline. The roadway generally runs in an east-west direction and provides a connection between the edge of Brighton and Newton to Commonwealth Avenue in Boston. The section of Beacon Street on the westbound side from Summit Avenue to Washington Street has no bicycles facilities and is particularly difficult for bicyclist. The Beacon Street pavement width is approximately 30' wide. The existing cross section consists of a parking lane and two westbound travel lanes. The streets steep uphill grade causes bicycles to travel at significantly slower speeds than vehicles. Vehicles are observed trying to pass bicyclists in the same travel lane however the provided lane width of 12.5' is below the recommended shared lane width. The posted speed limit along Beacon Street is 30 miles per hour (mph). Land use along Beacon Street is a mix of residential, medical and commercial uses in the study area.

Intersections

Marion Street meets Beacon Street to form a signalized T intersection. The Beacon Street westbound approach provides an exclusive left-turn lane and two through lanes with parking on the right. The Beacon Street eastbound approach provides an exclusive u-turn lane, a through lane and a right-through lane with parking on the right. The Marion Street northbound approach provides one general purpose travel lane that operates as two lanes. The MBTA Green C line tracks are located in the center median of Beacon Street. Land use at the intersection primarily consists of commercial and resident housing.

Short Street meets Beacon Street to form an unsignalized T intersection. The Beacon Street westbound approach provides a through lane and a right-through lane. The Short Street southbound approach provides one right turn only lane operating under stop control. Land use at the intersection is primarily residential.

Lancaster Terrace meets Beacon Street Westbound to form a signalized T intersection. The Beacon Street westbound approach provides a through lane and a right-through lane with parking on the right side of the street. The Lancaster Street Southbound approach provides one right turn only lane. The MBTA Green C line tracks are located in the center median of Beacon Street. Land use at the intersection primarily consists of medical and resident housing.

Westbourne Terrace meets Beacon Street to form an unsignalized T intersection. The Beacon Street westbound approach provides a right-through, through and U turn lane. The Beacon Street eastbound approach provides two through lanes and a U turn lane. Westbourne Terrace is one-way leaving Beacon Street. Land use at the intersection primarily consists of commercial and residential land uses.

Washington Street meets Beacon Street to form a signalized four way intersection. The Beacon Street westbound approach provides one through lane and one right-through lane with parking on both sides. The Beacon Street eastbound approach provides an exclusive left turn lane, a through lane and a right-through lane with parking on the right side of the street. The Washington Street northbound and southbound approaches each provide an exclusive left turn lane and a right-through lane. The MBTA Green C line tracks are located in the center median on Beacon Street. Land use at the intersection consists of commercial land uses.

TRAFFIC VOLUMES

Daily Traffic

An automated traffic recorder (ATR) was installed on Beacon Street and Lancaster Terrace near the study area for a 48-hour period in November 2012, June 2014, November 2014, and September 2015. The results of the counts are summarized in **Table 1** and **Table 2** below. The **Appendix** contains detailed count data.

Table 1
Beacon Street ATR Traffic Counts

	<u>Weekday</u> Daily Volume (vpd) ¹	<u>Weekday Morning Peak Hour</u> Percent Daily Traffic Volume (vph) ²	<u>Weekday Evening Peak Hour</u> Percent Daily Traffic Volume (vph) ²
<u>Beacon St Westbound</u>			
November 2012	11,130	639 5%	795 7%
June 2014	12,229	669 5%	955 8%
November 2014	11,953	697 5%	981 8%
October 2015	12,453	750 6%	1009 8%

¹One-way daily traffic expressed in vehicles per day.

²One-way peak hour volume expressed in vehicles per hour.

³WB = westbound

As summarized in **Table 1**, daily traffic volumes on Beacon Street for the westbound side near Lancaster Terrace are approximately 12,229 vehicles per day (vpd) during weekdays. Peak hour traffic flow on Beacon Street westbound is 5 to 8 percent of daily volumes. Updated counts were obtained in October 2015 after a signal timing and phasing was adjusted at the Beacon St at Webster St and Centre St intersection that had the potential to increase vehicle volume on Beacon Street. The updated October 2015 count does show a small increase in volumes that would have a nominal impact on operations.

Table 2
Lancaster Terrace ATR Traffic Counts

	<u>Weekday</u> Daily Volume (vpd) ¹	<u>Weekday Morning Peak Hour</u> Percent Daily Traffic Volume (vph) ²	<u>Peak</u> Flow Direction	<u>Weekday Evening Peak Hour</u> Percent Daily Traffic Volume (vph) ²	<u>Peak</u> Flow Direction
<u>Lancaster Terr</u>					
November 2012	780	71 9%	61%SB ³	59 7%	59%WB ³

¹Two-way daily traffic expressed in vehicles per day.

²Two-way peak hour volume expressed in vehicles per hour.

³SB = southbound

As summarized in **Table 2**, daily traffic volumes on Lancaster Terrace near Beacon Street are approximately 780 vpd during weekdays. Peak hour traffic flow on Lancaster Terrace is 7 to 9 percent of daily traffic volumes with peak flow approximately 60 percent southbound during the peak morning and evening hours.

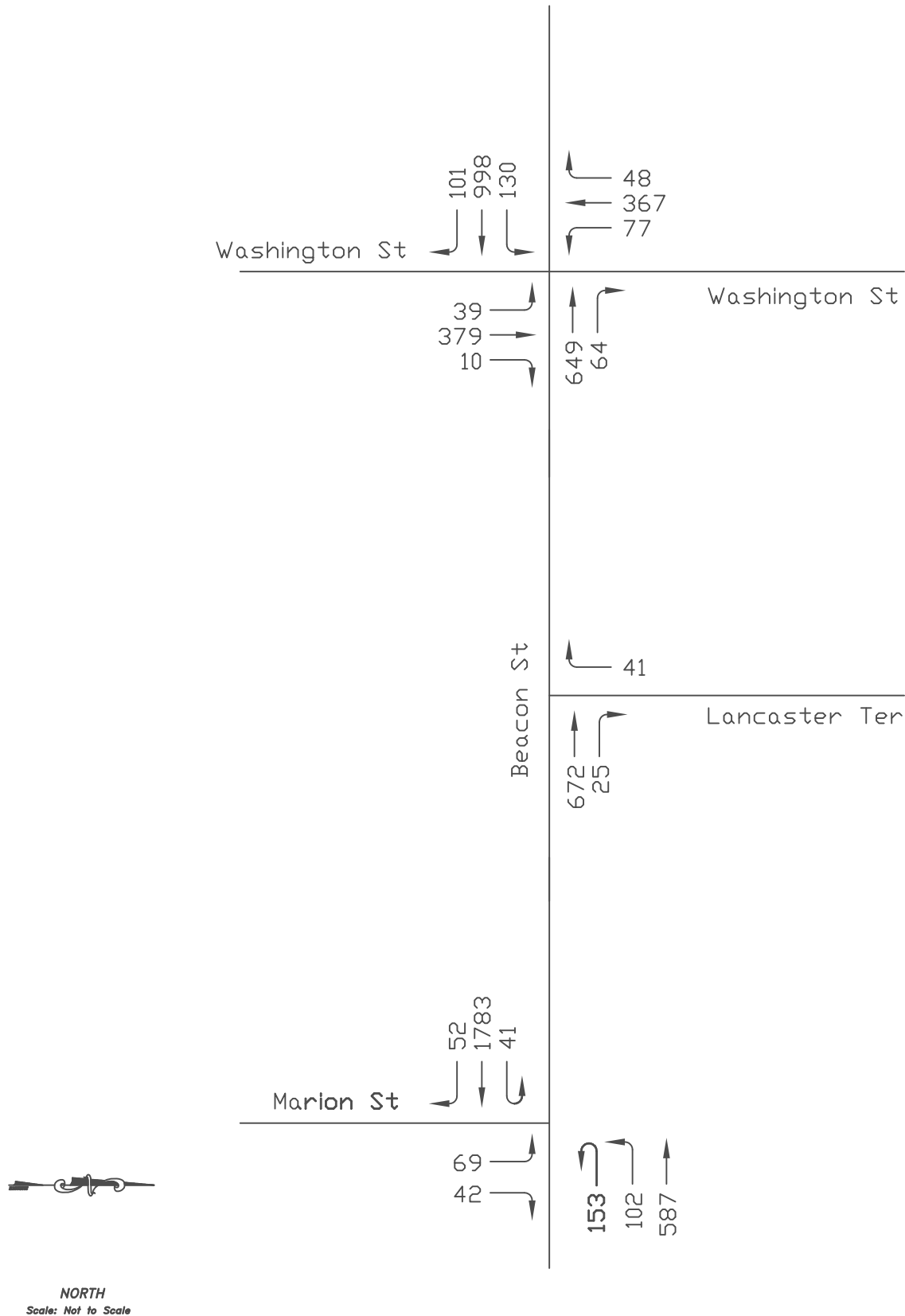
Peak Hour vehicle Volumes

The Brookline Bicycle Advisory Committee (BAC) annual fall bicycle counts reported 133 bicycles traveling outbound on Beacon Street near Short Street on September 22nd 2014 during the weekday evening peak period, 28 of the reported bicyclists where female. The 2014 counts show an 8% increase from the 2013 bicycle counts of 122 bicycles. The **Appendix** contains detailed BAC bicycle count data.

Turning movement counts (TMCs) for the corridor were taken from the 375-399 Chestnut Hill Avenue Draft Project Impact Report, Beacon Street Enhancement Project Study and adjusted to present day volumes using ATR count data taken in 2014. The Adjusted and balanced 2014 existing weekday evening and morning peak hour volumes are presented in **Figure 2 and Figure 3**. Detailed count data can be found in the **Appendix**.

In order to evaluate the potential for seasonal fluctuation of traffic volumes within the study area, MassDOT weekday seasonal factors for Group 6 roadways (urban arterials, collectors and rural arterials) were reviewed. Based on a review of this data, it was determined that traffic volumes for the month of November are approximately 3 percent above average-month conditions and, therefore, were not adjusted downward in order to provide a more conservative analysis condition.

Future year 2019 volumes are presented in **Figure 4 and Figure 5**. The Brookline area is already heavily developed and, therefore, an annual growth rate of 0.5 percent was selected to predict background future year traffic volumes. Currently no future developments are planned that will impact the study area.



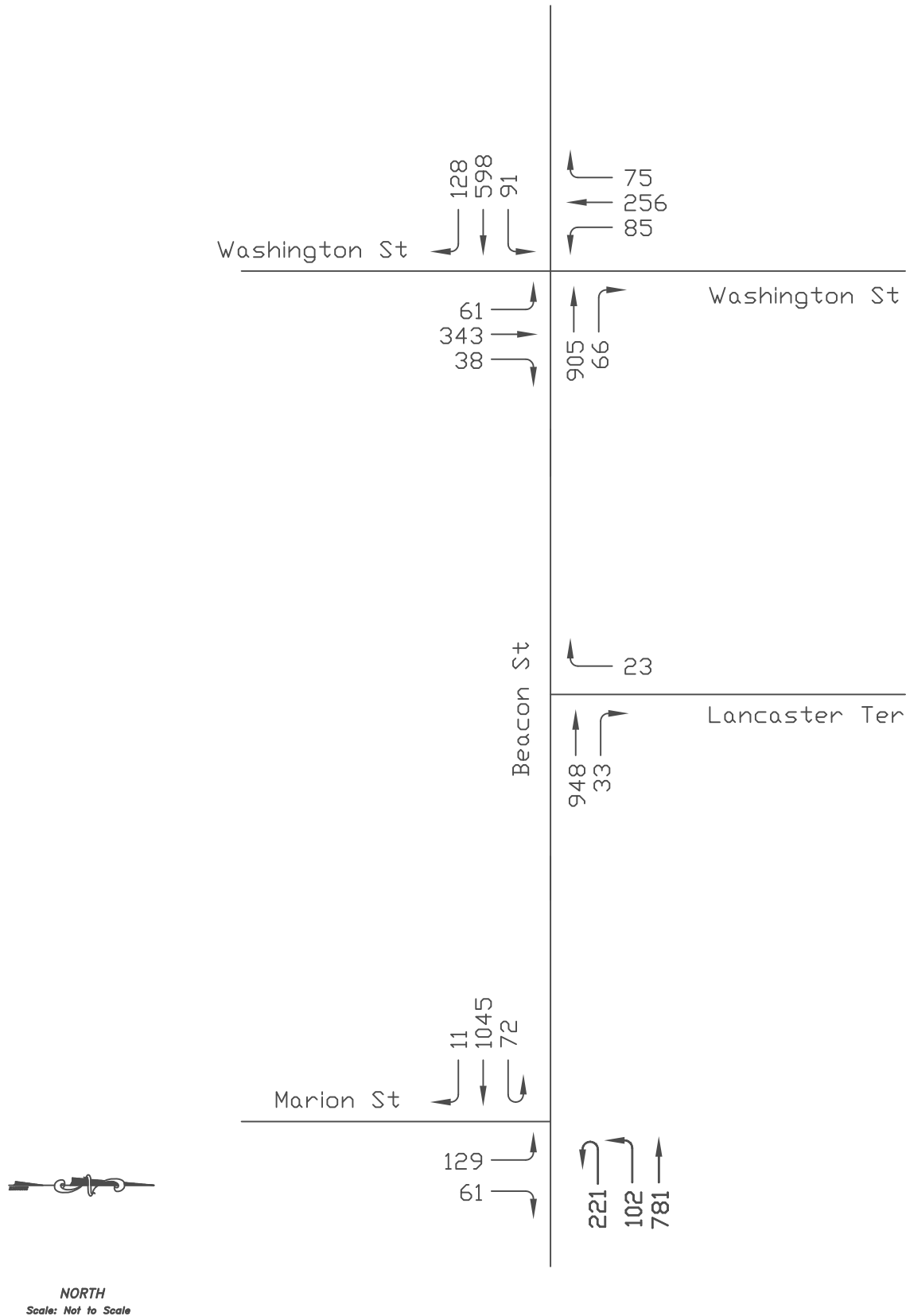
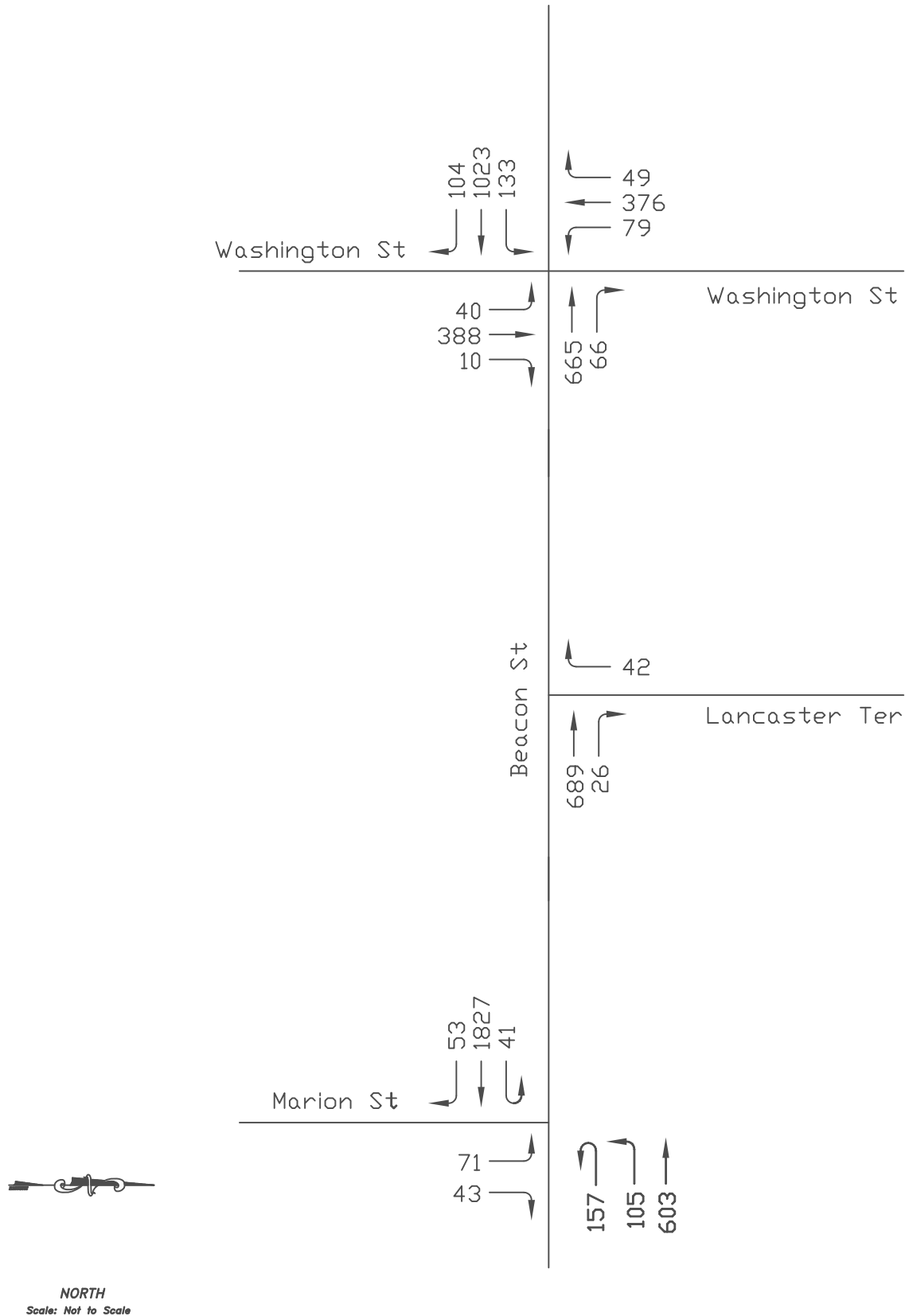
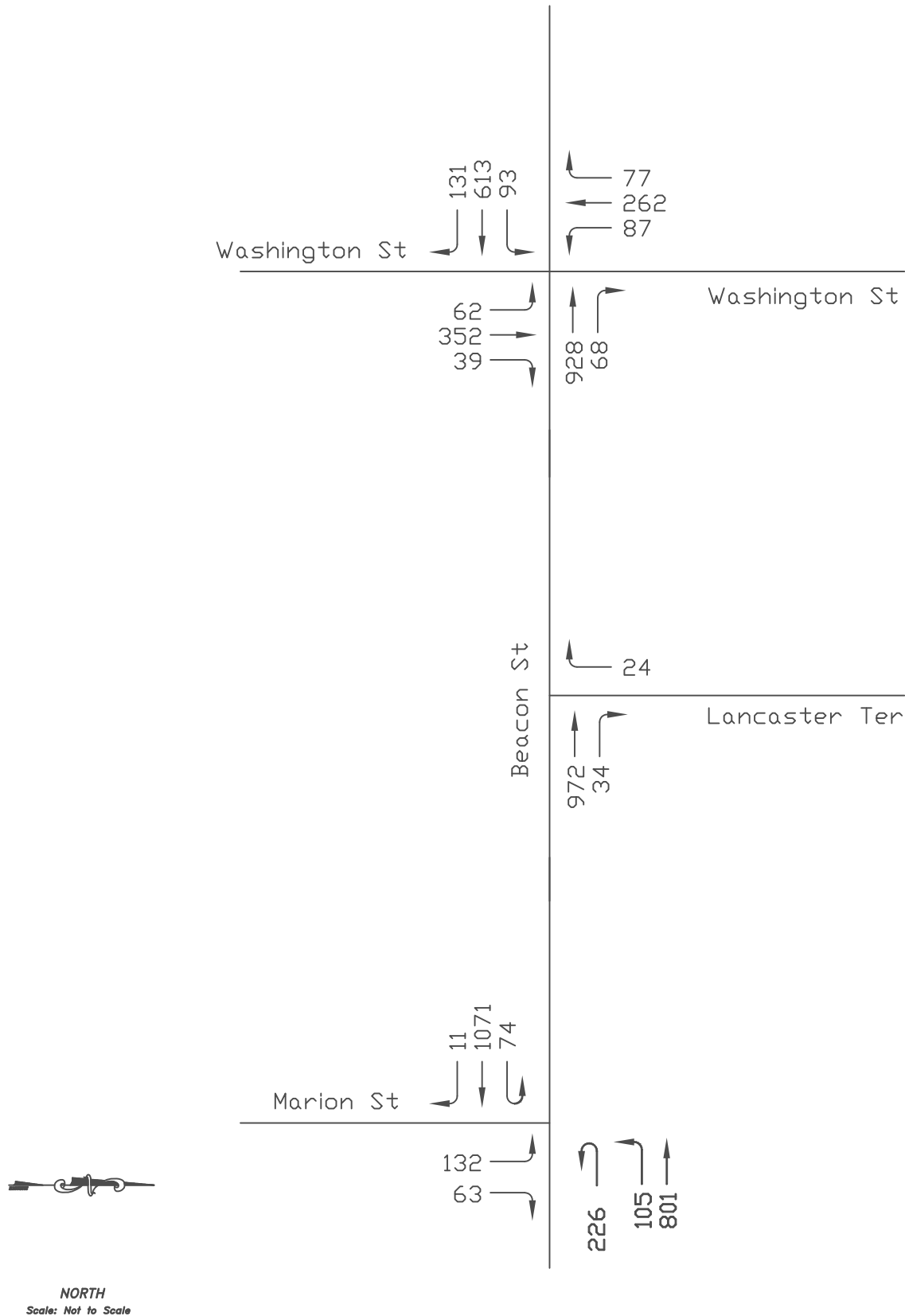


Figure 3

2014 Existing Weekday Evening
 Peak Hour Traffic Volumes





CRASH SUMMARY

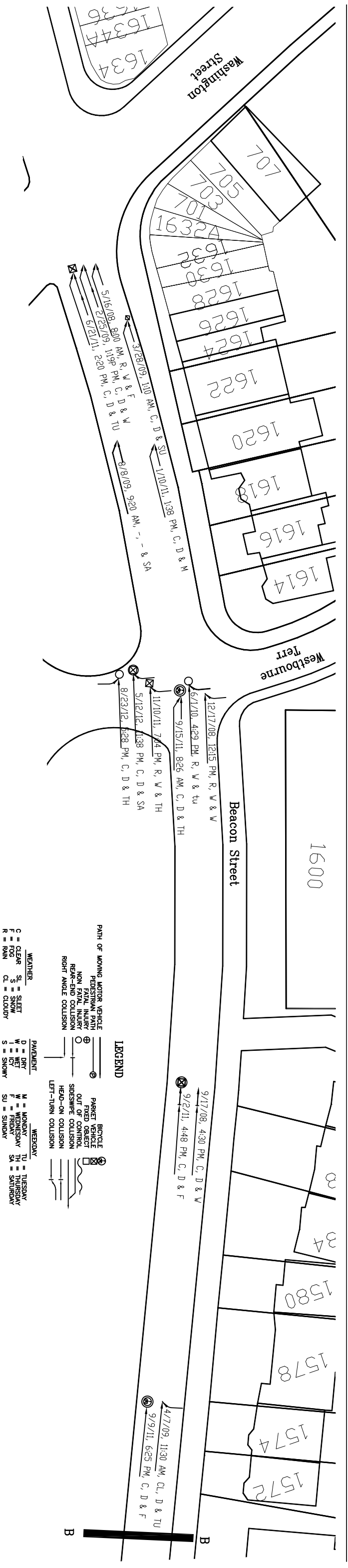
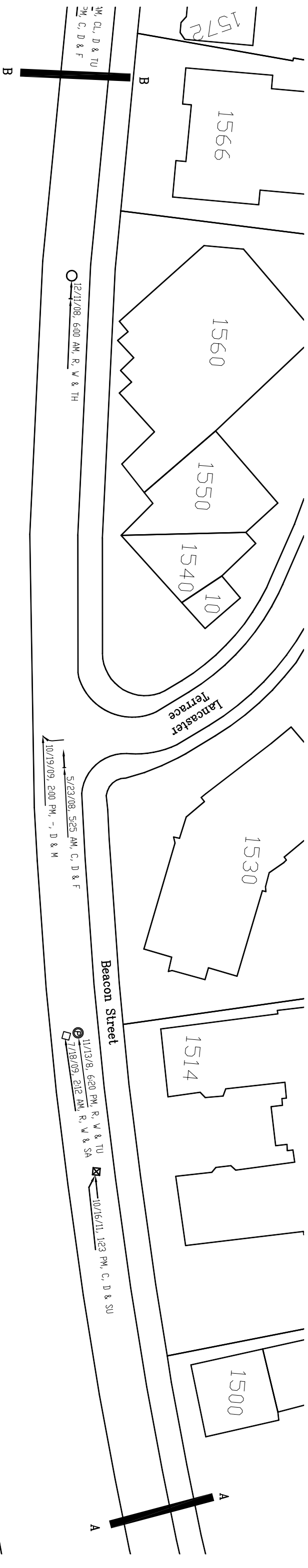
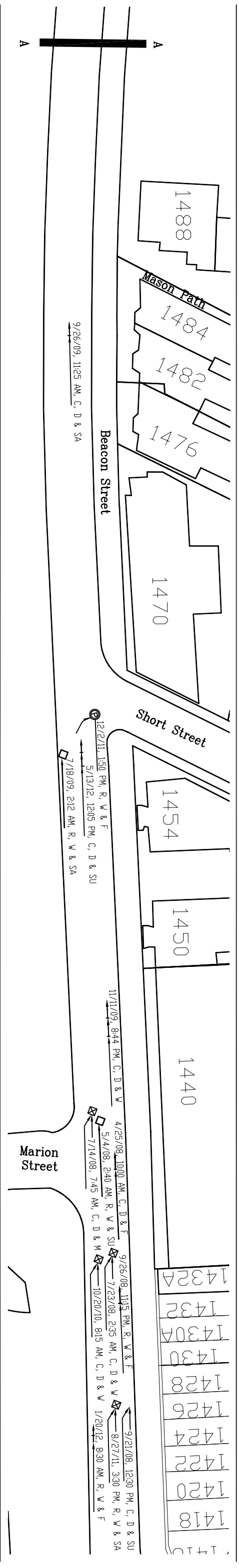
In order to identify accident trends and safety characteristics for the study corridor accident reports were obtained from MassDOT Crash Database for a five-year period covering 2008 through 2012. The accidents are detailed below in **Table 3**. The **Appendix** contains crash data from Mass DOT.

Table 3
Accident Summary

<u>Data Category</u>	<u>Beacon St</u> <u>WB at</u> <u>Marion St</u>	<u>Beacon St</u> <u>WB at</u> <u>Short St</u>	<u>Beacon St</u> <u>WB at</u> <u>Lancaster Ter</u>	<u>Beacon St</u> <u>WB at</u> <u>Westbourne Ter</u>	<u>Beacon St</u> <u>WB At</u> <u>Washington St</u>	<u>Beacon St</u> <u>At Other</u> <u>Locations</u>
Year:						
2008	4	0	1	1	1	5
2009	0	0	1	0	2	7
2010	0	0	0	1	0	0
2011	1	1	0	2	2	3
2012	<u>0</u>	<u>1</u>	<u>0</u>	<u>2</u>	<u>0</u>	<u>0</u>
Total	5	2	2	6	5	15
Type:						
Angle	0	1	1	5	0	1
Rear-End	2	1	1	0	0	5
Head-On	0	0	0	0	0	0
Sideswipe	2	0	0	1	5	4
Unknown/Other	1	0	0	0	0	5
Severity:						
P. Damage Only	4	1	2	2	4	7
Personal Injury	0	1	0	4	0	6
Fatality	0	0	0	0	0	0
Unknown/Other	1	0	0	0	1	2
Conditions:						
Dry	2	2	2	3	4	9
Wet	3	0	0	3	1	4
Snow/Ice	0	0	0	0	0	0
Other/Unreported	0	0	0	0	0	2
Time:						
7:00 AM to 9 AM	1	0	0	1	1	1
4:00 PM to 6 PM	0	0	1	2	0	2
Rest of Day	4	2	1	3	5	12

As summarized in **Table 3**, thirty five crashes were reported on the MassDOT crash database for Beacon Street westbound side from Marion Street to Washington Street for the five year period studied from 2008 to 2012. Two of the reported crashes involved a motor vehicle and bicyclist. The crash rate for the Beacon Street westbound corridor in the study area is 3.21, below the state average for an Urban Principal Arterial of 3.35. The crashes are depicted in **Figure 6** and the MassDOT rate work sheet can be found in the **Appendix**.

The Brookline Police department CAD activity report for Beacon Street westbound from 1420 Beacon Street to 1600 Beacon Street had fifty four traffic crashes reported 3 of which involved a Bicycle for the five year period studied from 2008 to 2012.



OPERATIONAL ANALYSIS

Capacity Analysis

In order to assess traffic operations at the interactions within the study area, capacity analysis was performed for each study intersections using the Synchro 7 Analysis tool. Synchro 7 methodology is based on the Transportations Research Boards' 2000 Highway Capacity Manual (HCM). The primary result of a capacity analysis is the assignment of Level of Service (LOS) to traffic facilities under various traffic flow conditions. LOS is a qualitative measure that describes operational conditions and provides an index to quality of traffic flow in terms of such factors as speed, travel time, freedom to maneuver, traffic interruptions, comfort, convenience, and safety.

There are six levels of service defined for each type of facility. They are given letter designations from A to F. LOS A represents the best operating condition and LOS F the worst. Since the LOS of traffic facility is a function of the traffic flows placed upon it, the LOS of a facility may vary greatly, depending on the time of day, weekday, or period of year. LOS for signalized and unsignalized interactions is calculated using the operational analysis methodology of the HCM.

The capacity analysis procedures for unsignalized intersections are provided for stop controlled interactions. LOS for unsignalized intersections is based on average control delay and is defined for each minor street movement. Average control delay includes initial deceleration delay, queue move up time, stopped delay, and final acceleration delay. LOS is not defined for an unsignalized interaction as a whole. The LOS criteria are provided in **Table 3** for unsignalized intersections.

LOS for signalized intersections is defined in terms of average control delay, which is a measure of driver discomfort, frustration, fuel consumption, and lost travel time. The LOS criteria for traffic signals are stated in terms of average control delay per vehicle. The average control delay includes initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay. Average control delay under signalized control is a complex measure and is dependent on a number of variables, including the quality of progression, the cycle length, the green ratio, and the volume-to-capacity ratio for the lane group in question. Table 3 also provides the LOS criteria for signalized interactions. In general, LOS D is considered acceptable in urban areas.

Table 3 – Level of Service Criteria

Level of Service	Signalized Intersections(sec/veh)	Unsignalized Intersections(sec/veh)	Signalized Intersections Level of Service descriptions
A	0-10	<10	Free Flow; Minimal delays
B	>10-15	>10-20	Low levels of delay and queuing
C	>15-25	>20-35	Backups may develop; Intermittently vehicles wait through more than one signal cycle.
D	>25-34	>35-55	Delays may become extensive; periodic cycles of lower demand occur to permit backups to clear.
E	>35-50	>55-80	Traffic fills capacity; long backups and delays. Many vehicles need to wait more than one signal cycle.
F	>50	>80	Traffic exceeded capacity; very long backups and delays. Most vehicles need to wait more than one signal cycle.

Capacity analysis was conducted for each of the three major intersections in the study area based on the existing 2014 traffic volumes as show in **Figure 2 and Figure 3** with the existing geometry and lane configuration. The Synchro 7 capacity analysis detailed reports are included in the **Appendix**. The capacity analysis results for each intersection are briefly discussed below and shown in **Table 4**.

The Beacon Street at Marion Street signalized intersection operates overall at a level of service C in the morning and evening with existing volumes and geometry.

The Beacon Street at Lancaster Terrace signalized intersection operates overall at a level of service A in the morning and evening with existing volumes and geometry.

The Beacon Street at Washington Street signalized intersection operates overall at a level of service C in the morning and evening with existing volumes and geometry.

Table 4 – Intersection Capacity Analysis

2014 Existing				2019 future volumes			2019 future volumes with proposed changes		
	v/c ¹	Delay ²	LOS ³	v/c ¹	Delay ²	LOS ³	v/c ¹	Delay ²	LOS ³
Beacon Street at Marion Street									
<i>Weekday Morning</i>									
EBL ⁴	0.23	39	D	0.23	39	D	0.23	39	D
EBT ⁴	1.00	43	D	1.07	67	E	1.07	67	E
WBL ⁴	0.71	41	D	0.73	42	D	0.73	42	D
WBT ⁴	0.25	6	A	0.26	6	A	0.26	6	A
NBT ⁴	0.46	32	C	0.47	32	C	0.47	32	C
Overall	1.00	35	C	1.07	50	D	1.07	50	D
<i>Weekday Evening</i>									
EBL ⁴	0.35	40	D	0.36	40	D	0.36	40	D
EBT ⁴	0.62	17	B	0.66	20	B	0.66	20	C
WBL ⁴	0.99	81	F	0.92	63	E	0.92	63	D
WBT ⁴	0.38	7	A	0.40	8	A	0.40	8	A
NBT ⁴	0.65	40	D	0.66	41	D	0.66	41	D
Overall	0.99	25	C	0.92	24	C	0.92	24	C
Beacon Street at Lancaster Terrace									
<i>Weekday Morning</i>									
WBT ⁴	0.32	8	A	0.33	9	A	0.57	6	A
SBR ⁴	0.08	0	A	0.18	25	C	0.10	1	A
Overall	0.32	7	A	0.33	10	A	0.54	5	A
<i>Weekday Evening</i>									
WBT ⁴	0.42	7	A	0.43	7	A	0.78	14	B
SBR ⁴	0.11	28	C	0.11	28	C	0.07	1	A
Overall	0.42	8	A	0.43	8	A	0.78	13	B
Beacon Street at Washington Street									
<i>Weekday Morning</i>									
EBL ⁴	0.49	40	D	0.50	40	D	0.50	40	D
EBT ⁴	0.60	15	B	0.62	16	B	0.62	16	B
WBT ⁴	0.53	23	C	0.55	24	C	0.55	14	C
SBL ⁴	0.55	39	D	0.57	40	D	0.57	40	D
SBT ⁴	0.76	35	D	0.77	35	D	0.77	35	D
NBL ⁴	0.32	28	C	0.33	29	C	0.33	29	C
NBT ⁴	0.70	33	C	0.71	33	C	0.71	33	C
Overall	0.76	24	C	0.77	25	C	0.77	25	C
<i>Weekday Evening</i>									
EBL ⁴	0.41	40	D	0.42	40	D	0.42	40	D
EBT ⁴	0.38	11	B	0.40	11	B	0.40	11	B
WBT ⁴	0.62	22	C	0.64	23	C	0.64	31	C
SBL ⁴	0.70	54	D	0.73	59	E	0.73	59	E
SBT ⁴	0.65	31	C	0.65	31	C	0.65	31	C
NBL ⁴	0.57	39	D	0.39	30	C	0.39	30	C
NBT ⁴	0.73	36	D	0.74	36	D	0.74	36	D
Overall	0.73	24	C	0.74	25	C	0.74	28	C

Note: ¹Volume-to-capacity ratio²Average Control Delay³Level of service⁴EBL=Eastbound Left, EBT=Eastbound Through, WBL=Westbound Left, WBT=Westbound Through, SBL=Southbound Left, NBL=Northbound Left, NBT=Northbound Through

Capacity Analysis Future and Proposed Conditions

Beacon Street has an approximately pavement width of 30' with a cross section consisting of two travel lanes of 10.5' and 12.5' with a 7' parking lane. To accommodate a separate on street bicycle facility for the Beacon Street westbound side from Short Street to Westbourne Terrace one vehicle travel lane will need to be removed.

A painted buffered bicycle lane was chosen to provide an enhanced level of comfort for bicyclist while still allowing room for vehicles to pull onto the painted area out of the way of a passing emergency vehicle when needed. The proposed corridor improvements are depicted in **Figure 7**.

The buffered bicycle lane begins 250 feet west of Marion Street allowing the Beacon Street at Marion Street Signalized Intersection to continue operating with two westbound departure lanes. If a travel lane were removed closer to Marion Street analysis shows significant queueing that would impact the Beacon Street at Summit Avenue intersection and extend to the Beacon Street at Winchester Street Intersection during the evening peak period.

To accommodate the removed travel lane at the Beacon Street at Lancaster Terrace intersection a number of signal modifications are proposed. The signal will be coordinated with the Beacon Street corridor to promote better vehicle progression from Marion Street. Right turn movements on red from Lancaster Terrace onto Beacon Street will be allowed and a delay of 10 seconds will be added for the Lancaster Terrace approach before a call is put into the signal. The pedestrian crossing for Lancaster Terrace will be changed from an exclusive movement to a concurrent movement with Beacon Street.

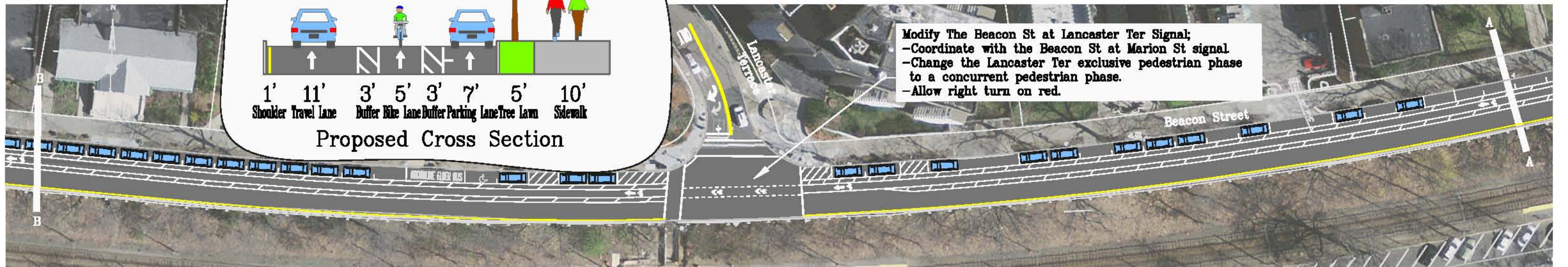
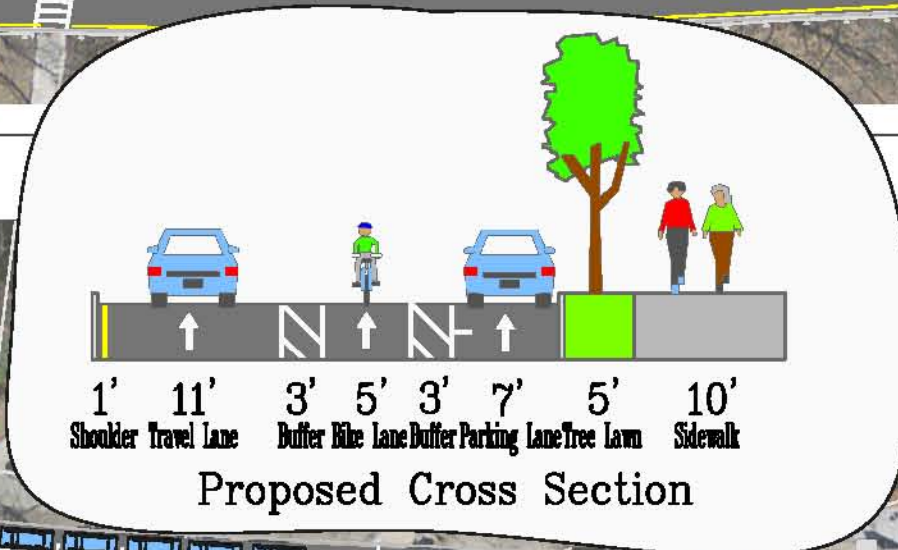
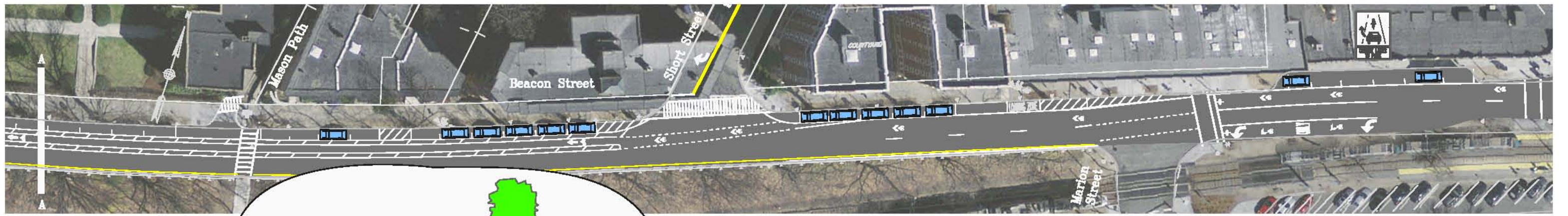
The buffered bicycle lane ends 440' before Washington Street and becomes a shared vehicle and bicycle lane. The buffered bicycle lane ends at this point to accommodate the weekday evening queue at the Beacon Street and Washington Street signalized intersection.

Capacity analysis was conducted for each of the three major intersections in the morning and evening peak hour with the future 2019 volumes from **figure 3** and **figure 4**. Then capacity analysis was conducted with the proposed signal modifications and lane configuration with the future 2019 volumes. Capacity analysis for each intersection are briefly discussed below and shown above in **Table 4**. The Synchro 7 reports are included in the **Appendix**.

The Beacon Street at Marion Street signalized intersection operates overall at a level of service D in the weekday morning peak hour and LOS C in the evening peak hours with future 2019 volumes and the proposed corridor bicycle improvements have minimal impact on intersection capacity.

The Beacon Street at Lancaster Terrace signalized intersection operates overall at a level of service A in the morning and evening peak hours with future 2019 volumes. With the proposed corridor bicycle improvements, the morning peak hour continues to operate with LOS A and degrades slightly in the weekday evening peak hour to a LOS B. Although the LOS is acceptable the removed lane will cause significant queue lengths. These backups are discussed in greater detail below in the Vehicle queue analysis section. Allowing vehicles to make a right on red from Lancaster Terrace onto Beacon Street improves the Lancaster Terrace approach LOS from a C to LOS A in the peak hours.

The Beacon Street at Washington Street signalized intersection operates overall at a level of service C in the morning and evening with future 2019 volumes and the proposed corridor bicycle improvements have minimal impact on intersection capacity.



Modify The Beacon St at Lancaster Ter Signal;

- Coordinate with the Beacon St at Marion St signal.
- Change the Lancaster Ter exclusive pedestrian phase to a concurrent pedestrian phase.
- Allow right turn on red.



Vehicle Queue Analysis

Vehicle queues are presented below in **Table 5** for the three study intersections. These vehicle queue lengths are compared to available storage lengths, which are defined as lengths of exclusive turn lanes or the distance to the nearest major signalized intersection for through lanes. The queue lengths are defined for the 50th percentile queue as occurring 1/2 the signal cycles and the 95th percentile queue length occurs 1/20 of the signal cycles during the peak hour.

Table 5 – Intersection Queue Length Analysis

		2014 Existing		2019 Future Volumes		2019 Proposed Changes	
		50 th	95 th	50 th	95 th	50 th	95 th
	Storage	Queue	Queue	Queue	Queue	Queue	Queue
<i>Beacon Street Westbound at Marion Street</i>							
<i>Weekday Morning</i>							
EBL ⁴	140'	23'	53'	23	53'	23	53'
EBT ⁴	1,220'	~632''	#831'	~665'	864'	~665'	#864'
WBL ⁴	140'	142'	#246'	146'	257'	146'	#257'
WBT ⁴	190'	61'	84'	63'	84'	35'	67'
NBT ⁴	>500'	46'	93'	47'	95'	47'	95'
<i>Weekday Evening</i>							
EBL ⁴	140'	40'	79'	41'	80'	41'	80'
EBT ⁴	1,220'	227'	303'	250'	330'	250'	#330'
WBL ⁴	140'	194'	#372'	194'	#359'	194'	#359'
WBT ⁴	190'	64'	124'	106'	196'	111'	194'
NBT ⁴	>500'	92'	161'	95'	166'	95'	166'
<i>Beacon Street at Lancaster Terrace</i>							
<i>Weekday Morning</i>							
WBT ⁴	1,100'	80'	120'	88'	141'	87'	112'
SBR ⁴	>400'	0'	0'	16'	38'	0'	0'
<i>Weekday Evening</i>							
WBT ⁴	1,100'	70'	199'	73'	207'	243'	#823'
SBR ⁴	>400'	6'	30'	7'	31'	0'	0'
<i>Beacon Street Westbound at Washington Street</i>							
<i>Weekday Morning</i>							
EBL ⁴	200'	72'	121'	73'	123'	73'	123'
EBT ⁴	>500'	210'	327'	222'	338'	222'	338'
WBT ⁴	>500'	162'	271'	170'	280'	130'	286'
SBL ⁴	60'	37'	81'	38'	83'	38'	83'
SBT ⁴	>500'	215'	289'	220'	299'	220'	299'
NBL ⁴	80'	17'	43'	18'	44'	18'	44'
NBT ⁴	>500'	200'	269'	204'	276'	204'	276'
<i>Weekday Evening</i>							
EBL ⁴	200'	51'	94'	52'	95'	52'	95'
EBT ⁴	>500'	106'	178'	112'	184'	112'	184'
WBT ⁴	>500'	225'	409'	238'	#426'	302'	#444'
SBL ⁴	60'	44'	#97'	46'	#111'	46'	#111'
SBT ⁴	>500'	161'	221'	165'	228'	165'	228'
NBL ⁴	80'	46'	89'	29'	60'	29'	60'
NBT ⁴	>500'	200'	265'	205'	274'	205'	274'

Note: ¹WBL=Westbound Left, WBT=Westbound Through, SBR=Southbound Right

= 95th Percentile exceeds capacity, queue may be longer. ~ = Volume exceeds capacity, queue is theoretically infinite
Queue shown is maximum after two cycles

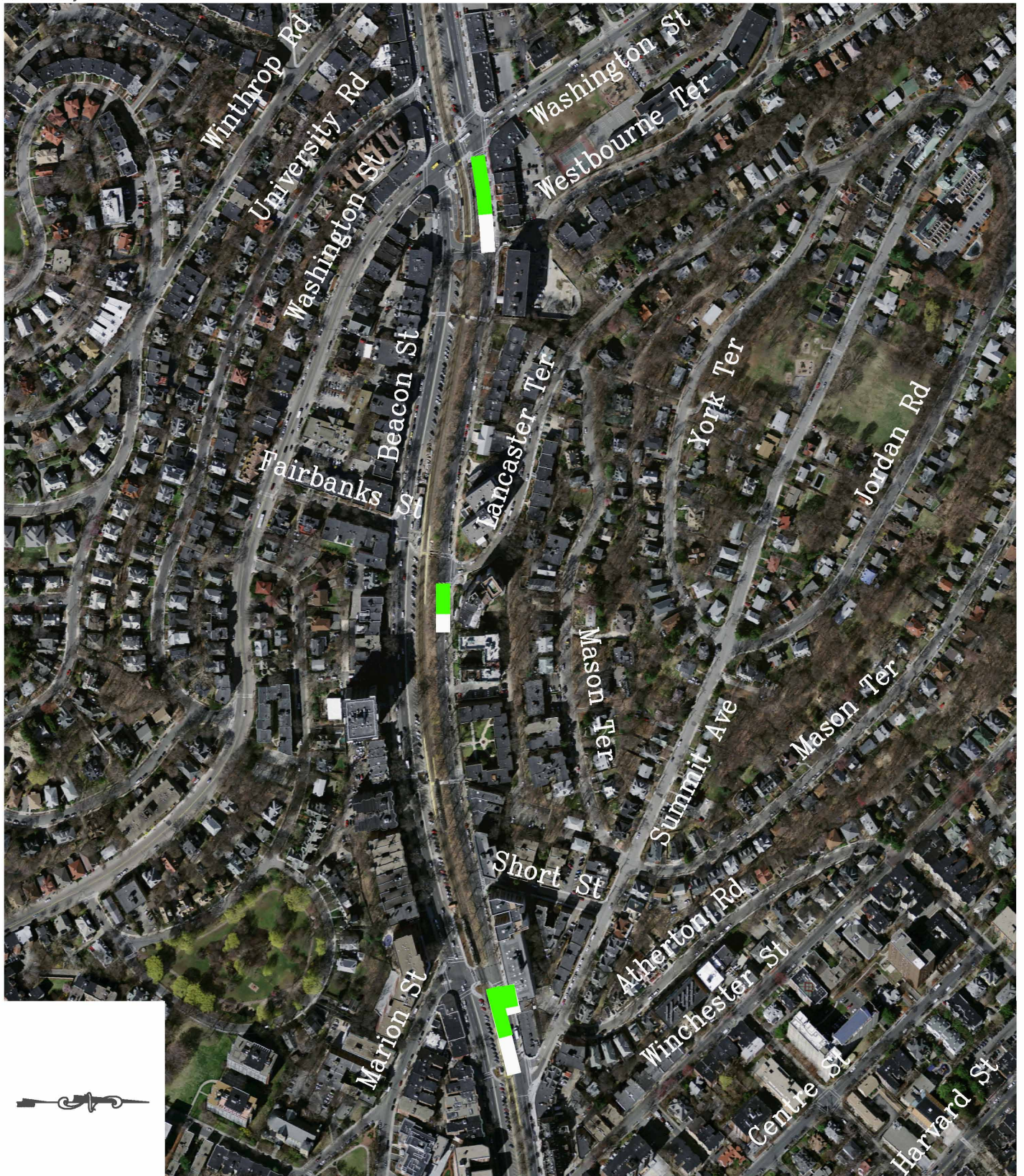
⁴EBL=Eastbound Left, EBT=Eastbound Through, WBL=Westbound Left, WBT=Westbound Through,
SBL=Southbound Left, NBL=Northbound Left, NBT=Northbound Through

Figure 8 and **Figure 9** graphically depict the Beacon Street westbound 2019 future vehicle queues without the proposed lane reduction and **Figure 10** and **Figure 11** depict the Beacon Street westbound 2019 future vehicle queues with the proposed lane reduction. The results for each intersection are briefly discussed below and Synchro 7 reports are included in the **Appendix**.

The Beacon Street westbound at Marion Street vehicle queues are contained within available storage lanes during peak hours except for the westbound left turn vehicle queues. The proposed buffered bicycle lane on Beacon Street starting at Short Street does not increase vehicle queues at this intersection compared with the queue lengths with 2019 future year traffic volumes with the existing Beacon Street geometry and signal operations.

The Beacon Street at Lancaster Terrace vehicle queue lengths are significantly impacted by the removal of a travel lane, 95th percentile queues in the evening peak hour increase from 216' feet or approximately 8 cars to 824' or approximately 33 cars. This section of Beacon Street is within an area without any other major intersection and is able to accommodate the increased vehicle queue without any major conflicts. Although the queue length is substantial by coordinating the Beacon Street at Lancaster Terrace signal with the Marion Street signal, traffic operations are anticipated to operate at a level of service B or an average vehicle delay of 13 seconds.

The Beacon Street westbound approach at Washington Street vehicle queue of 444' is contained within available storage lanes during peak hours. The proposed signal changes at the Beacon Street at Lancaster Terrace intersection have a minimal impact on queue lengths at the Beacon Street at Washington Street intersection.



NORTH

Scale: 1"=400'

■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 8

Future 2019 Weekday Morning
 Peak Hour Queue Lengths



NORTH
Scale: 1"=400'

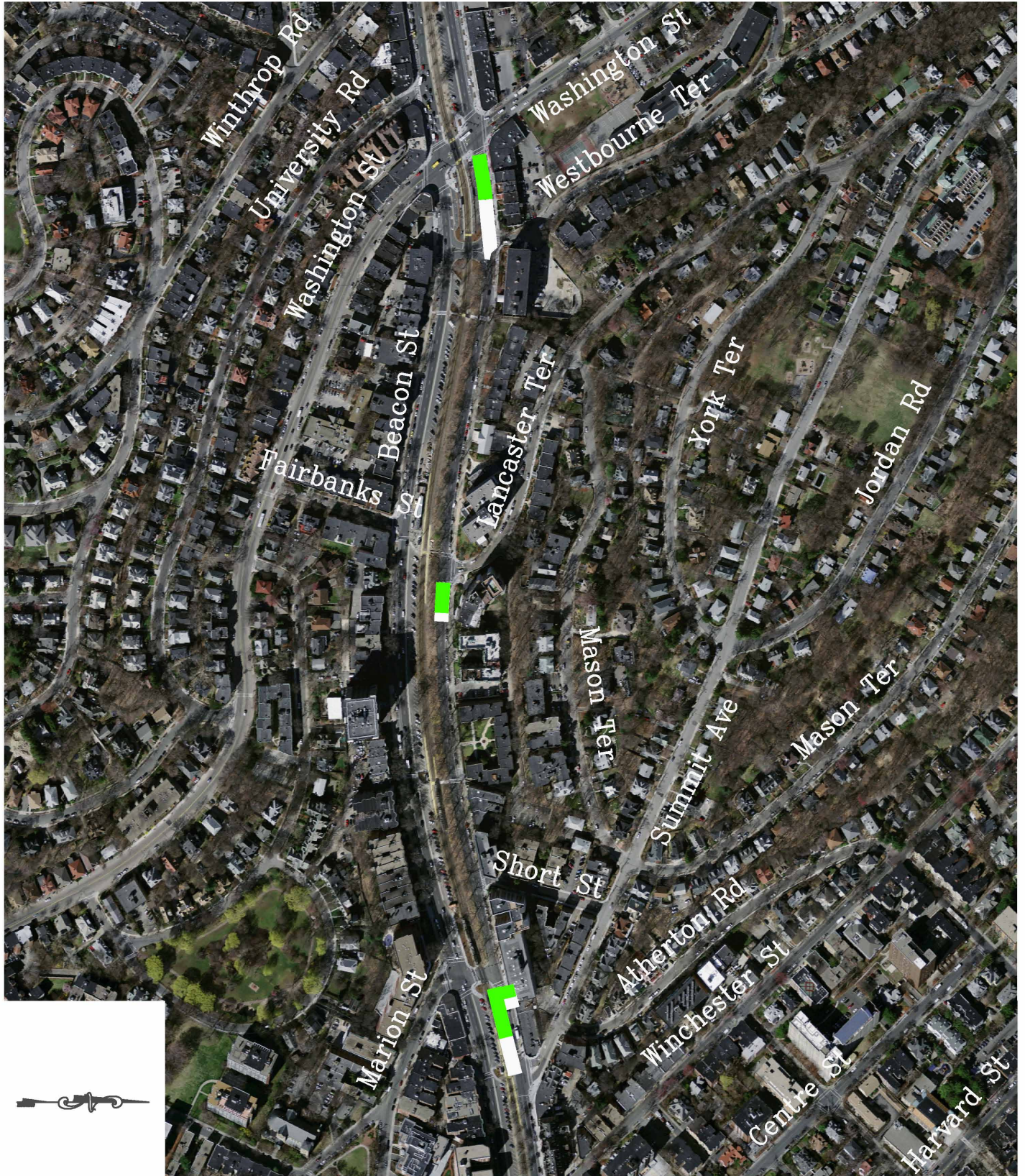
■ = 50th Percentile Queue
□ = 95th Percentile Queue

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Figure 9

Future 2019 Weekday Evening
Peak Hour Queue Lengths



NORTH

Scale: 1"=400'

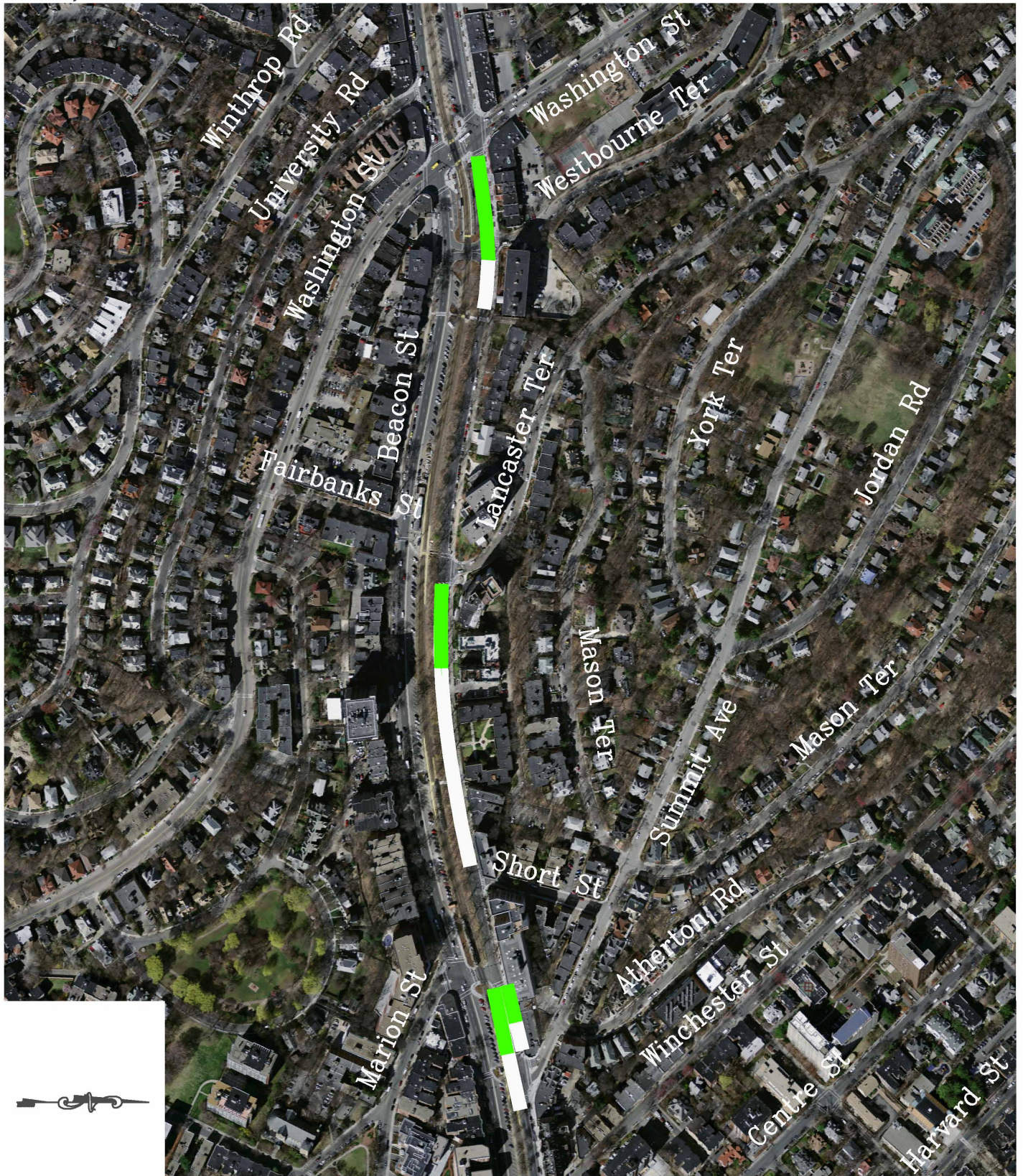
■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 10

Proposed 1 lane 2019 Weekday Morning
 Peak Hour Queue Lengths



NORTH
 Scale: 1"=400'

■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 11

Proposed 1 lane 2019 Weekday Evening
 Peak Hour Queue Lengths

Vehicle Queue Observations

Queue length observations were made in November 2012, June 2014 and November 2014 vehicle queues observations are presented below in **Table 5**. These vehicle queue lengths are compared to available storage lengths, which are defined as lengths of exclusive turn lanes or the distance to the nearest major signalized intersection for through lanes.

Table 6 – Beacon Street at Marion Street
Queue Length Observations

		June 2014		June 2014		November 2014	
		Existing Geometry		With Proposed Changes		With Proposed Changes	
		50 th	95 th	50 th	95 th	50 th	95 th
	Storage Length	Queue Length	Queue Length	Queue Length	Queue Length	Queue Length	Queue Length
<i>Beacon Street Westbound at Marion Street</i>							
<i>Weekday Midday</i>							
WBL ¹	140'	75'	150'	75'	175'	100'	200'
WBT ¹	190'	125'	350'	175'	275'	100'	275'
<i>Weekday Evening</i>							
WBL ¹	140'	75'	200'	100'	175'	100'	225'
WBT ¹	190'	100'	200'	125''	375'	225'	400'
<i>Beacon Street Westbound at Lancaster Terrace</i>							
<i>Weekday Midday</i>							
WBT ¹	1,100'	50'	175'	150'	400'	125'	300'
<i>Weekday Evening</i>							
WBT ¹	1,100'	50'	225'	200'	900' ²	325'	900' ²

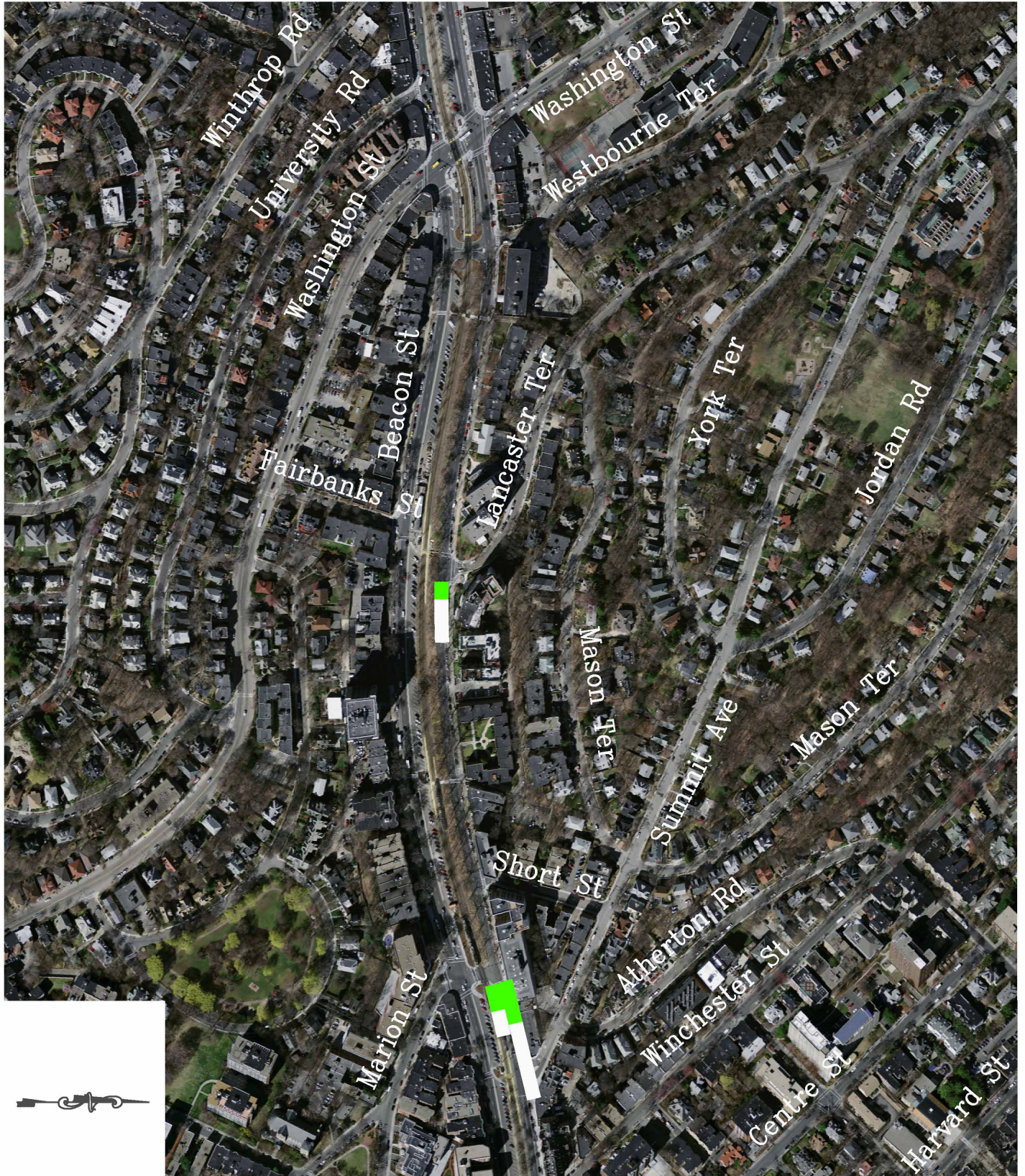
Note: ¹WBL=Westbound Left, WBT=Westbound Through

²Observed queue was beyond view and exceeded 650', estimated at 900'

Figure 12 and **Figure 13** graphically depict observed Beacon Street westbound vehicle queues in June 2014 without the proposed lane reduction or signal improvements and **Figure 14** and **Figure 15** depict observed vehicle queues in November 2014 with the proposed lane reduction.

The Beacon Street westbound at Marion Street Queue length observations were longer than queue lengths predicted in the Synchro 7 analysis. The longer than expected queues were likely the result of cars occasionally double parking blocking a travel lane and a curiosity factor as drivers slow down to observe the lane drop and coned off bicycle lane during the trial period. Vehicle queue lengths extended into the adjacent Summit Ave at Beacon Street Intersection but did not reach Winchester Street at Beacon Street intersection.

The Beacon Street westbound at Lancaster Terrace queue length observations were longer than the predicted Synchro 7 analysis average queues. The 95th percentile queue went beyond view at approximately 26 vehicles or 650'. The end of queue was observed a couple of occasions reaching beyond Short Street and impacting the proposed merge near the Beacon Street at Marion Street signal. The longer than predicted queues may have been caused by a curiosity factor as drivers slowed down to observe the lane drop and coned off bicycle lane during the trial period.



NORTH
 Scale: 1"=400'

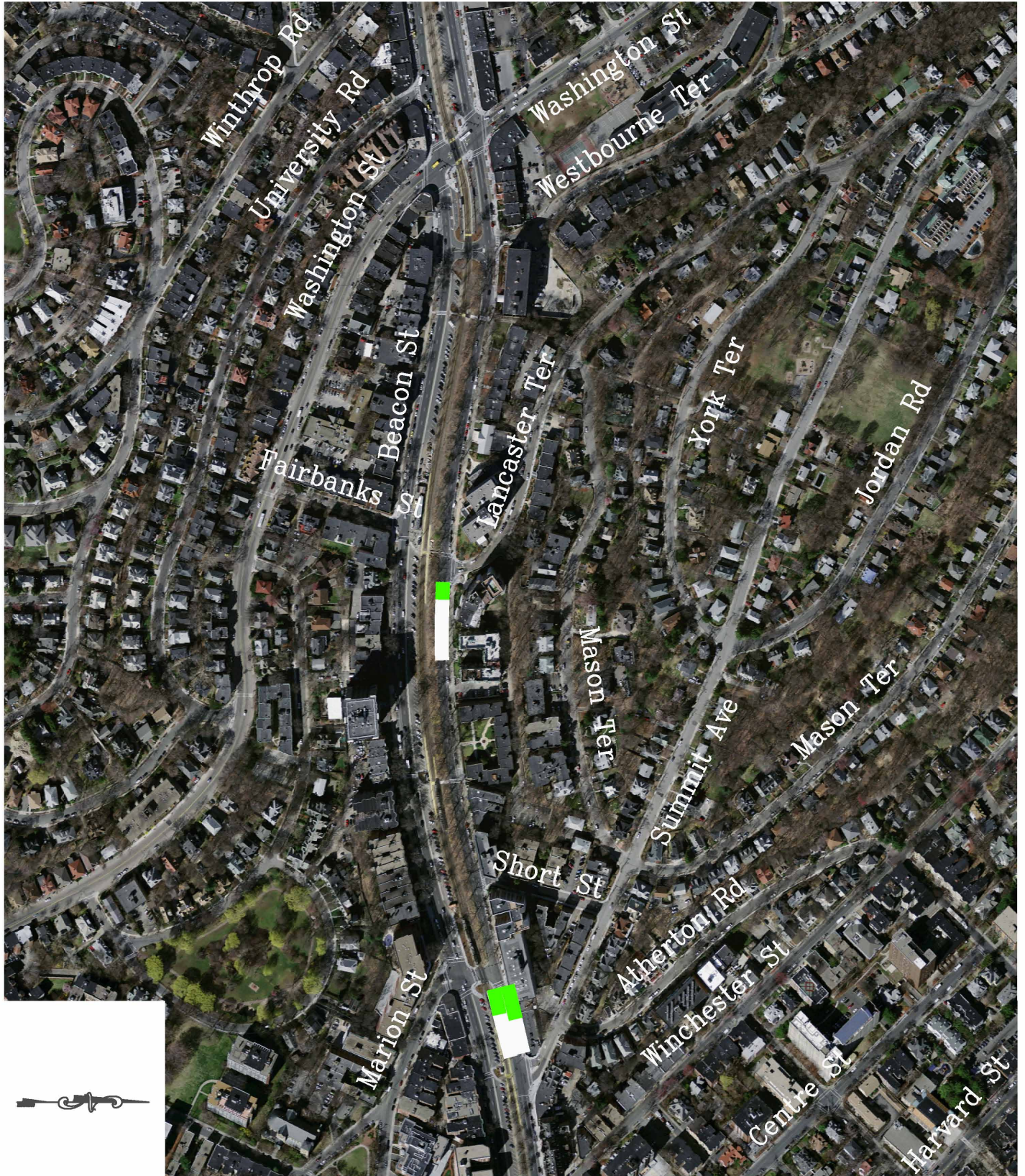
■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 12

Existing 2014 Weekday Afternoon
 Observed Queue Lengths



NORTH
 Scale: 1"=400'

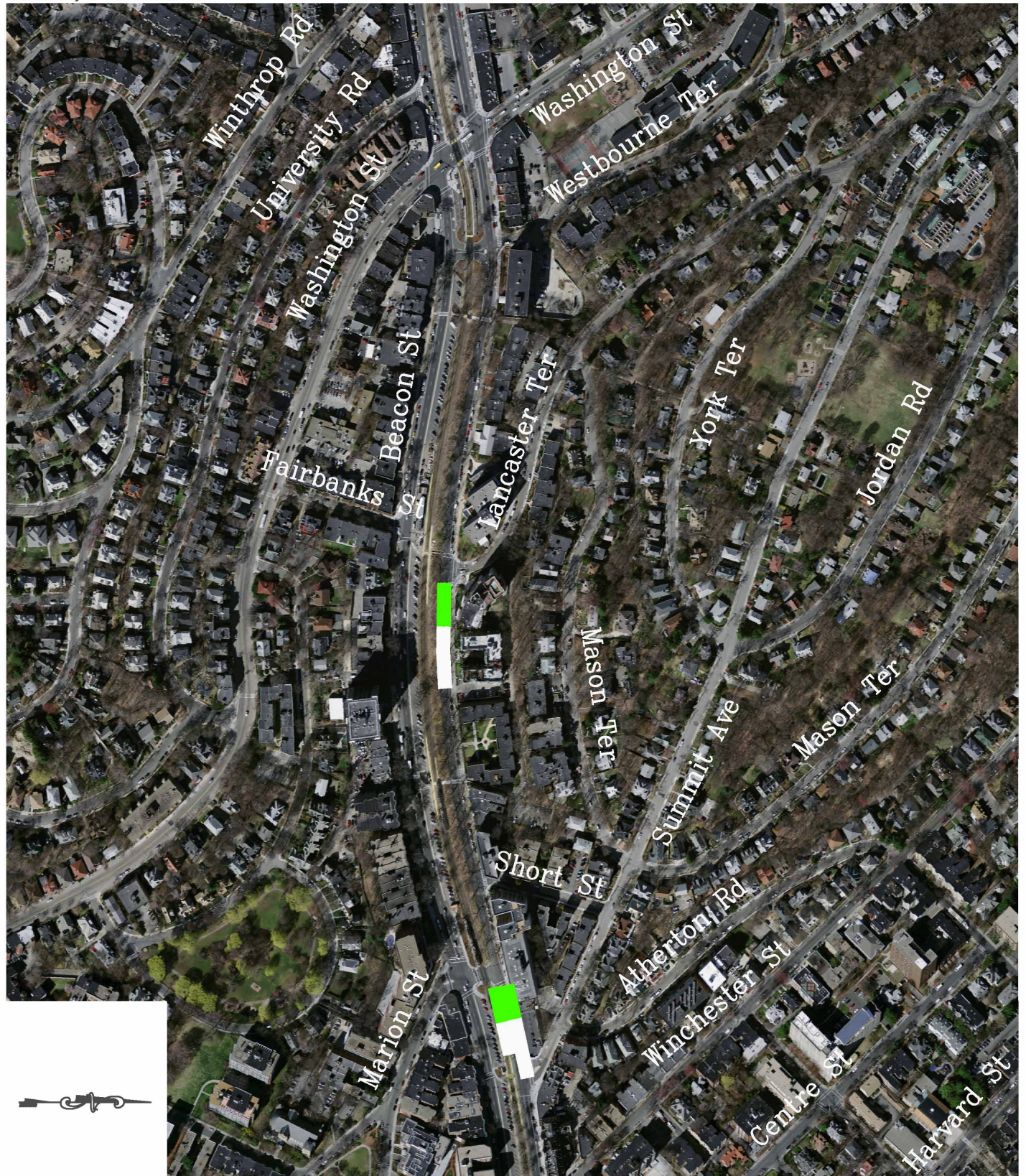
■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 13

Existing 2014 Weekday Evening
 Observed Queue Lengths



NORTH
 Scale: 1"=400'

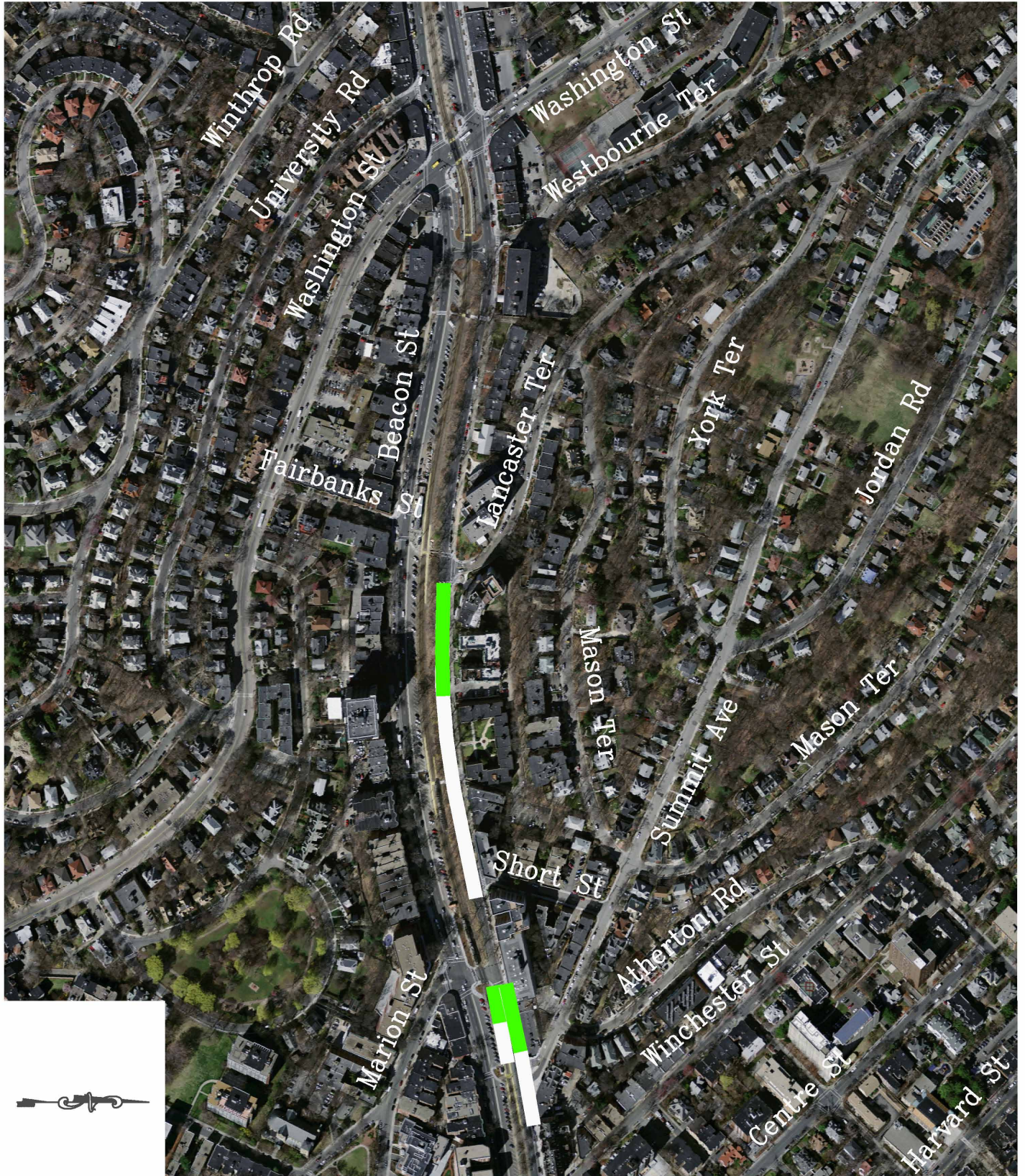
■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 14

Proposed 1 lane 2019 Weekday Afternoon
 Observed Queue Lengths



NORTH
 Scale: 1"=400'

■ = 50th Percentile Queue
 □ = 95th Percentile Queue

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Figure 15

Proposed 1 lane 2019 Weekday Evening
 Observed Queue Lengths

CONCLUSION

The installation of a Buffered Bicycle lane on Beacon Street starting near Short Street and ending near Westbourne Terrace as shown in **Figure 7** is recommended. Providing a Bicycle lane will provide a complete street enabling safe access for all users, including bicyclists, pedestrians, motorists and transit riders of all ages and abilities. This section of Beacon Street is also identified in the Brookline Green Routes Bicycle Network Plan as a particularly dangerous section for cyclists. The steep uphill grade poses particular difficulty for slow moving bicycles to share a lane with cars.

To install a bicycle lane one travel lane will need to be removed. Based on the capacity analysis of the westbound side of Beacon Street from Marion Street to Washington Street it is possible to remove a travel lane to accommodate a bike lane. The most significant impact is at the Beacon Street at Lancaster Terrace intersection, overall intersection level of service in the evening will degrade from an A to a B and vehicle queuing is anticipated to be substantial.

The Beacon Street westbound weekday evening 95th percentile queue at the Lancaster Terrace and Beacon Street intersection will go from 216' feet or approximately 8 cars to 824' or approximately 33 cars. This queue will at times end near Short Street. The anticipated queue is stored within an area without any major intersections mitigating potential conflicts.

During field observations conducted in June 2014 and November 2014 with the proposed travel lane removed 95th percentile queueing did exceed predictions from the Synchro 7 analysis. On a few occasions during the evening peak hour queueing from the Beacon Street at Lancaster Terrace intersection did impact departing vehicles from the Beacon Street at Marion Street signal. This may be attributed to occasional double parked cars on Beacon Street near Marion Street and a curiosity factor as drivers slowed down during the trial period to observe the lane drop and coned off bicycle lane.

To improve signal operations as an effort to mitigate the removal of a travel lane at the Beacon Street at Lancaster Terrace intersection a number of signal modifications are proposed. The signal will be coordinated with the Beacon Street corridor to promote better vehicle progression from Marion Street. Right turn movements on red from Lancaster Terrace onto Beacon Street will be allowed and a delay of 10 seconds will be added for the Lancaster Terrace approach before a call is put into the signal. The pedestrian crossing for Lancaster Terrace will be changed from an exclusive pedestrian movement to a concurrent pedestrian movement with Beacon Street.